Chapter 6. Tidal Hydraulics

This chapter describes the existing tidal hydraulic regime of the project area, the impacts of the alternatives on circulation and sedimentation in San Pablo Bay, the ability of the proposed tidal channels to transport sediment and create the tidal marsh, and the effects of wind and wave action on perimeter levees.

Affected Environment

Data Sources

Information presented in this section is based on the following sources:

- Clarification of Wetland Design Issues for Hamilton Marsh Restoration Project (Baye pers. comm.);
- Suspended Particle Transport and Circulation in San Francisco Bay: An Overview, in Estuarine Processes—Volume II (Conomos and Peterson 1977);
- Wind in California (California Department of Water Resources 1978);
- Sacramento—San Joaquin Delta Atlas (California Department of Water Resources 1993);
- Sediment Budget Study for San Francisco Bay (U.S. Army Corps of Engineers 1992);
- Review of Model Plans for the John F. Baldwin Ship Channel Project (U.S. Army Corps of Engineers 1996c);
- U.S. Geological Survey (USGS) 7.5-minute quad sheets for Petaluma Point, California (printed 1951, photorevised 1968, photorevised 1980) and Novato, California (printed 1954, photorevised 1968, photorevised 1980); and
- tidal benchmark data (Tide Gage 941-5252).

Existing Tidal Hydraulic Regime

Unless otherwise cited, all information in this section is developed from or reported in Conomos and Peterson (1977).

San Pablo Bay is the northernmost embayment of the San Francisco Bay system. At high tide, the surface area of the bay is approximately 64,000 acres. Tidal circulation in San Pablo Bay is determined by the bay's connection with San Francisco Bay to the south. San Pablo Bay directly receives most of the freshwater inflow entering the San Francisco Bay system. This freshwater inflow has an extensive influence on current patterns, vertical mixing, and constituent transport patterns within San Pablo Bay. During periods of high inflow, the bay becomes well mixed, and salinity stratification and intrusion are diminished.

More than 90% of the freshwater inflow to San Pablo Bay arises from the Sacramento and San Joaquin River systems and enters the bay through Carquinez Strait. The combined flow of these rivers averages approximately 32,000 cfs during the winter months and average approximately 6,000 cfs during the summer months (California Department of Water Resources 1993). The remainder of the freshwater inflow to San Pablo Bay enters through numerous tidal creeks and pump station outfalls that drain the bay's tributary watersheds. The largest of these watersheds draining into San Pablo Bay enter along the bay's northern shoreline, including the Napa River, Sonoma Creek, and the Petaluma River.

Currents in San Pablo Bay are dominated by tidal circulation. Based on measurements of tidal stage fluctuation and the tidal prism volume upstream of a given point, the average tidal discharges at Chipps Island, just downstream of the confluence of the Sacramento and San Joaquin Rivers, is estimated to be 170,000 cfs and increases to more than 2,300,000 cfs at the Golden Gate (California Department of Water Resources 1993). Average tidal discharges in San Pablo Bay increase with increasing tidal prism volume; thus, the greatest tidal discharge on San Pablo Bay occurs on its southern boundary with central San Francisco Bay.

Tidal stage in San Pablo Bay follows a mixed semi-diurnal pattern, meaning that there are two distinct high tides of different elevations and two distinct low tides of different elevations in any given lunar day. The mean lower low water elevation at the Petaluma River entrance tide gage is -2.63 feet NGVD. The mean higher high water elevation is 3.43 feet NGVD. Storm surge and wind setup can increase tidal water surface elevations well in excess of the mean higher high water elevation. Peak 100-year tidal flood elevations are reported as 7.0 feet NGVD in the draft restoration plan.

Sediment inflow to the bay from the Delta system is highly variable, with values as high as 3.8 million tons per year. Sediment inflow is projected to decrease to approximately 1.6 million tons per year by 2035 as a result of increased flow diversions from the Delta (U.S. Army Corps of Engineers 1992). The sand/silt/clay ratio of sediment reaching the San Francisco Bay system is estimated at 15%, 30%, and 55%, respectively. Sediment input to the bay is directly linked to the quantity of water entering the bay and primarily derives from winter flood runoff events. The Sacramento and San Joaquin River system contributes more than 80% of their combined sediment load during winter storm events. Suspended sediment concentrations within the waters of San Pablo Bay vary with the intensity of wind mixing and the quantity entering from freshwater inflows.

The morphology of San Pablo Bay is characterized by extensive mudflat and subtidal mud surfaces and a primary 30- to 40-foot-deep subtidal channel extending from the confluence with San Francisco Bay to Carquinez Strait. This subtidal channel is periodically dredged by the Corps for deep draft navigation to the ports of Richmond, Mare Island, Pittsburg, Antioch, Stockton, and Sacramento (U.S. Army Corps of Engineers 1996c). A smaller subtidal channel approximately 8 feet deep at mean lower low water traverses the mudflats from the mouth of the Petaluma River to the primary subtidal channel. The mudflats outside of the subtidal channels slope gently upwards through the tidal range to the bay's shoreline. Average depths are less than 6 feet over much of the mudflat and subtidal mud surfaces. The shoreline fringe is tidal marsh, whose width varies from less than 100 feet in many locations to several hundred feet along the bay's northern shoreline.

Wind speeds over San Pablo Bay are light and variable. Winds exceed 13 mph only 10% of the time. Median wind speeds are less than 7 mph (California Department of Water Resources 1978). Wind-generated waves develop in response to the wind patterns, with resultant wave height and wave period being a function of fetch length and water depth. Resultant wave periods of 2–5 seconds are reported as typical for conditions in San Pablo Bay.

The restoration site is on the western shoreline of San Pablo Bay. Historically, the project site was a tidal marsh and hydraulically connected to San Pablo Bay. Placer mining in the middle to late 1800s introduced tremendous amounts of sediment to the San Pablo Bay, causing extensive deposition and progradation of the shoreline. Levees and drainage facilities constructed in the late 1800s eliminated tidal exchange into the historical marsh area.

Comparison of USGS quad sheets (Petaluma Point, 7.5-minute series, 1951, 1959, 1980) of the study area indicate that marsh accretion is occurring in the outboard marsh adjacent to San Pablo Bay. This observation indicates that sufficient suspended sediment is transported to the marsh front and is deposited to create new marsh plain on the western shoreline of San Pablo Bay.

Environmental Consequences and Mitigation Measures

This section describes methods used to analyze potential impacts of the project alternatives compared to conditions under Alternative 1: No Action. Potential impacts and impact mechanisms of each project alternative are described, and recommended mitigation measures to reduce significant impacts to a less-than-significant level are provided.

Approach and Methods

Potential impacts on the tidal hydraulic regime and morphology of San Pablo Bay and its environs were determined by comparing the magnitude of the relevant tidal hydraulic parameters under existing conditions with the expected magnitude of the tidal hydraulic parameters after implementation of the various project alternatives.

Impact Mechanisms

The following types of activities and processes associated with implementation of the project alternatives could result in changes in tidal hydraulic circulation or morphologic processes in San Pablo Bay or the restored tidal wetlands on the HAAF, SLC, and BMKV parcels.

Circulation and Morphology of the San Pablo Bay

Tidal and Residual Circulation in San Pablo Bay. Creation of additional tidal prism on the western shoreline of San Pablo Bay would induce tidal currents into and out of the tidal prism of the restored tidal wetland. This action may alter circulation patterns within San Pablo Bay.

Morphology of San Pablo Bay and Shoreline. The project would involve construction of tidal outlet channels through the existing outboard salt marsh and mudflats. Additional morphologic adjustments and changes within San Pablo Bay may develop over time.

San Pablo Bay Sediment Budget. The project is designed to trap suspended sediment from San Pablo Bay. Sediment deposition within the restored wetlands may affect the overall sediment budget and existing sediment deposition patterns within San Pablo Bay.

Circulation and Morphology of Proposed Tidal Wetlands

Tidal and Residual Circulation in Proposed Tidal Wetlands. The project would create tidal circulation and inundation on properties that are presently protected by levees and drained by the existing HAAF pump stations and perimeter drainage ditch.

Internal Peninsulas and Perimeter Levees. The project would create tidal currents adjacent to internal peninsulas intended to dissipate wave action and the project perimeter levee. Tidal inundation would allow for wind-wave action on these structures that could induce erosion or morphologic change over time.

Thresholds of Significance

In this analysis, a project alternative is considered to have a significant impact on the tidal hydraulic environment if it would:

- alter the magnitude and direction of tidal circulation outside the immediate zone of subtidal and outboard marsh channels constructed for the project;
- alter the large-scale morphology of mudflats and subtidal channels outside the immediate zone of subtidal and outboard marsh channels constructed for the project;
- cause erosion of the perimeter levees, thus increasing the risk of tidal flooding on adjacent properties;
- induce or aggravate erosion of the existing outboard salt marsh; and
- cause insufficient sediment deposition within the tidal marsh to develop morphologically, as described in the draft restoration plan~~; and~~.
- ~~cause persistence of internal peninsulas.~~

Impacts and Mitigation Measures of Alternative 1: No Action

Maintaining the HAAF and SLC parcels in their present uses would have no impact on the tidal hydraulic environment in San Pablo Bay or the properties on which tidal wetlands are proposed to be created. The DoD would continue to maintain the properties in caretaker status. Continued operation and maintenance of the interior drainage system and San Pablo Bay levee would continue. The existing outboard tidal marsh, San Pablo Bay mudflats, and subtidal channels would be unaffected.

Impacts and Mitigation Measures Common to Alternatives 2, 3, 4, and 5

Impact 6.1: Modification to Circulation in San Pablo Bay

Tidal fluctuations into and out of the restored tidal wetland would generate tidal currents in and adjacent to the subtidal channels that connect the restored tidal wetland with San Pablo Bay. This would affect the area around the outboard marsh and subtidal channels because flow momentum in the subtidal channels would be rapidly dissipated by tidal waters outside the subtidal channels. This impact is considered less than significant because large-scale circulation patterns within San Pablo Bay would not be affected by the proposed action.

Impact 6.2: Modification to Sedimentation Processes and Morphology in San Pablo Bay

The HAAF tidal basin is designed to be a sink for sediments carried by tidal exchange, and thus could affect sedimentation and morphology in San Pablo Bay. The sediment sources include bay muds resuspended by wave activity and fine suspended sediment carried from upland sources draining into San Pablo Bay. This impact is considered less than significant because the total amount of suspended sediment deposition within the proposed tidal wetland over the 50-year project horizon is, at most, 7% of the annual suspended sediment (3.8 million tons per year) inflow to San Pablo Bay.

Impact 6.3: Changes in Circulation and Morphologic Evolution in Tidal Wetland

For the tidal marsh to evolve as described in the draft restoration plan, adequate conveyance must be provided by the connecting subtidal inlet and levee breach channels to allow full tidal exchange with the constructed tidal basins. For channel widening to occur in the subtidal channel, adequate shear stress must be developed to erode the consolidated bay mud sediments. As presented in the draft restoration plan, a subtidal connection channel would be excavated through the existing outboard marsh. The invert of the subtidal channel would be equivalent to the invert elevation of the levee breach channel; however, the subtidal channel would be narrower and shallower than the proposed ultimate levee breach channel for the tidal prism volume of the restored wetland. This channel configuration would create a choke through the undersized channel, resulting in a net vertical range of tidal fluctuation in the constructed wetlands that may be less than the vertical tide range in San Pablo Bay. Limited tidal exchange could inhibit the ability of tidal currents to develop the required shear stress to erode and transport the channel boundary materials. This sediment transport feedback process may inhibit morphologic evolution of the proposed wetlands to such a degree that project objectives may not be achieved; therefore, the loss of biological resources (described in Chapter 8) may not be offset by the proposed project. Therefore, this impact is significant. To mitigate this impact to a less-than-significant level, the Coastal Conservancy, Corps, or successors in interest shall implement Mitigation Measure 6.3.

Mitigation Measure 6.3: Ensure Adequate Tidal Exchange and Develop and Implement a Monitoring Program to Assess Project Evolution. To identify and develop effective mitigation measures for unexpected or undesirable tidal hydraulic and morphologic response within the restored tidal wetland, the Coastal Conservancy, Corps, or successors in interest shall ensure that a monitoring program is developed that is tied to the project goals and objectives (described in Chapter 2) and implemented to assess project evolution. The monitoring program should include, at a minimum, the following elements:

- **Time period:** Until criteria are met, with annual review of monitoring results; the monitoring period may be discontinued, or monitoring and review intervals lengthened, if the results indicate successful evolution of the wetlands toward the targets of the draft restoration plan

- **Parameters to be monitored:** Tidal stage, tidal current, wind speed and direction, wave characteristics, suspended sediment concentrations, marsh elevation, mudflat elevation, characteristics of subtidal channel and marsh surface sediments, and San Pablo Bay shoreline characteristics

- **Locations to be monitored:** Tidal wetland interior, tidal wetland perimeter, subtidal channels, and existing San Pablo Bay marsh shoreline

- **Frequency of monitoring:** To be recommended in monitoring program

Monitoring of morphologic evolution will allow the state and federal governments to assess the success of creating the target habitat characteristics and make corrective actions for achieving the desired habitat types. Potential corrective actions include changing the breach and subtidal channel dimensions, altering perimeter levee berm morphology, and modifying channel characteristics within the restored tidal wetlands to ensure adequate morphologic evolution.

In addition to this monitoring program, a quantitative assessment of subtidal channel shear stress and resultant subtidal channel widening should be completed before project construction to ensure that adequate tidal exchange within the restored wetlands would occur. One potential method for completing this assessment includes ~~laboratory measurements of the critical shear stress for erosion of the bay muds, and use of these parameters in numerical modeling analysis. This numerical modeling can be combined with determination of long-term "effective" suspended sediment concentrations in San Pablo Bay by collection of sediment cores in existing accreting marsh surfaces in the project area, and calculating the required concentration to develop the sediment accumulation rates determined from the core samples. This will provide a more accurate assessment of the time frame required for sediment deposition and the resultant tidal habitat to develop within the restored wetland.~~ :

- obtaining a few undisturbed cores of the tidal muds to determine critical shear stress for particle and mass erosion of the cohesive muds (critical shear stress of muds is a function of the degree of consolidation, the clay mineral types, and other geochemical factors; it is not purely a function of grain diameter as it is for noncohesive sands and gravels) and

- completing a two-dimensional (depth-averaged) hydrodynamic analysis of the proposed tidal wetland and tidal mudflats in the vicinity of the tidal wetland;

  the modeling analysis would determine whether the conveyance provided in the entrance channel and subtidal mudflat channel is sufficient to scour the cohesive bay muds; the analysis completed to date has not addressed the effects of the mudflat entrance conditions and thus neglects a critical link in the system; flow over the mudflat (through subtidal mudflat channels) must be adequate to reach the outboard marsh entrance channel; if the entrance and mudflat channel are too small, the tidal flushing and sediment input to the wetland will be limited, and the marsh plain will not develop as projected.

Impact 6.4: Inception of or Increase in Outboard Marsh Shoreline Erosion

Tidal circulation between the restored tidal marsh and San Pablo Bay is not expected to induce or aggravate erosion of existing tidal marsh shoreline along San Pablo Bay. However, the project would involve excavation of a channel or channels through the existing outboard marsh. Additional erosion of the outboard marsh surface can be expected if the channel or channels widen in response to the tidal exchange to the restored wetlands. The loss of existing tidal marsh is considered a less-than-significant impact because a primary purpose of the proposed action is the creation of new and additional tidal marsh habitat. The project is designed to create tidal marsh habitat over and above the amount lost by excavation and erosion of the connecting outboard marsh channel.

Impact 6.5: Excessive or Unexpected Erosion of Perimeter Levee

The perimeter and New Hamilton Partnership levees would be subject to erosion from current or wave forces. Currents generated by tidal fluctuations adjacent to levee structures within the proposed wetlands are not expected to pose a significant erosion risk to the structures. Final design studies completed before project implementation are recommended to quantify tidal currents within the wetland and determine erosion risk from tidal currents.

Wind-generated waves pose a more significant erosion risk than tidal currents on the perimeter and New Hamilton Partnership levees. The size of wind generated waves is primarily a function of the wind speed, wind fetch, wind duration, and water depth. Wave height generally increases in magnitude with each of these parameters. Erosion from wind-generated waves can be minimized or eliminated by adequately providing for wave dissipation and erosion protection structures on the levee structures or minimizing the opportunity for wind waves to develop. The design presented in the conceptual plan utilizes a combination of levee berms for providing wave dissipation and erosion protection and methods for and internal peninsulas for lowering wave fetch and resultant wave height.

Philip Williams & Associates (1998) developed unpublished information regarding storm-generated wind waves in the proposed tidal wetlands. Their analysis of wind-generated waves with a 100-year recurrence interval within the proposed tidal wetlands indicates wave heights of 1.7, 1.9, and 2.0 feet for fetch lengths of 2,000, 4,000, and 8,000 feet, respectively. Fetch lengths were determined by utilizing internal peninsulas within the tidal wetland. Wave runup elevations for these three wave heights differed by no more than 0.3 foot for a variety of berm and levee slope conditions. For practical purposes, the difference in wave heights for the different internal peninsula configurations, and the resultant wind fetch lengths, are very small. Nearly equivalent erosion protection measures would be required for the three different wave heights. The small differences in wave runup could be accounted for by constructing a levee with a slightly higher final crest elevation, indicating that internal peninsulas may not be required as part of the levee erosion protection measures. Material for constructing levees approximately 0.3 foot higher could be obtained by eliminating internal peninsulas and utilizing these embankment materials to increase levee and levee berm dimensions.

A submerged berm and wildlife corridor are proposed for installation on the perimeter levees and New Hamilton Partnership levees, respectively. Properly designed, these types of structures can be effective measures for providing wave dissipation, erosion protection, and a substrate for vegetation establishment. Berm erosion would expose the perimeter and New Hamilton Partnership levees to wave erosion, threatening levee integrity. Design details to ensure adequate berm performance, including berm topslope, berm length, and elevation, would be determined during final design studies of the wetland restoration project.

The conceptual plan recommends that levee erosion monitoring and maintenance be part of the project design. The monitoring and maintenance program could include surveying levee berm topography and assessing vegetation establishment annually after project construction. The monitoring could be accomplished by surveying berm and levee cross sections annually at a maximum spacing of 2,500 feet. The levee erosion monitoring program should be incorporated into any additional monitoring required for ensuring geotechnical stability and adequate crest elevations of the levee structure. Adverse erosion identified by the monitoring program could be corrected by placement of additional berm material, installation of acceptable erosion control features such as fiber mats, planting of vegetation, or installation of riprap. A properly designed and executed monitoring and repair program, in conjunction with properly sized levees and levee erosion protection measures, would prevent any significant impacts caused by levee erosion; therefore, the impact of perimeter levee erosion is considered less than significant.

Potential Issues and Resolutions under the Bel Marin Keys V Scenario

One possible future scenario is that the BMKV property could be converted to tidal and nontidal wetlands connected to the HAAF and SLC parcels. This conversion would increase the tidal prism of the wetland and could have a cumulative effect on circulation, sedimentation, and morphologic evolution in San Pablo Bay and in the HAAF and SLC parcel wetlands.

The additional tidal prism is not considered to be large enough to have cumulative impacts on San Pablo Bay. Issues regarding the BKMV conversion on the proposed project in the HAAF and SLC parcels would need to be addressed in BKMV project design and environmental documentation.